mined not by the motion of one rope alone, but by that of several, and suppose, further, that all this machinery is silent and utterly unknown to the men at the ropes, who can only see as far as the holes in the floor above them.

Supposing all this, what is the scientific duty of the men below. They have full command of the ropes, but of nothing else. They can give each rope any position and any velocity, and they can estimate its momentum by stopping all the ropes at once, and feeling what sort of tug each rope gives. If they take the trouble to ascertain how much work they have to do in order to drag the ropes down to a given set of positions, and to express this in terms of these positions, they have found the potential energy of the system in terms of the known co-ordinates. If they then find the tug on any one rope arising from a velocity equal to unity communicated to itself or to any other rope, they can express the kinetic energy in terms of the co-ordinates and velocities.

These data are sufficient to determine the motion of every one of the ropes when it and all the others are acted on by any given forces. This is all that the men at the ropes can ever know. If the machinery above has more degrees of freedom than there are ropes, the co-ordinates which express these degrees of freedom must be ignored. There is no help for it.

Of course, if there are co-ordinates for which there are no ropes, but which enter into the expression for the energy, then, if the motion of these co-ordinates is periodic, there will be "adynamic vibrations" communicated to the ropes, and by these the men below will know that there is something peculiar going on above them. But if they pull the ropes in proper time, they can either quiet these adynamic vibrations or strengthen them, so that in this case these co-ordinates cannot be ignored.

There are other cases, however, in which the conditions for the ignoration of co-ordinates strictly apply. For instance, if an opaque and apparently rigid body contains in a cavity within it an accurately balanced body, mounted on frictionless pivots, and previously set in rapid rotation, the co-ordinate which expresses the angular position of this body is one which we are compelled to ignore, because we have no means of ascertaining it. An unscientific person on receiving this body into his hands would immediately conclude that it was bewitched. A disciple of the northern wizards would prefer to say that the body was subject to gyrostatic domination.

Of the sections on cycloidal motions of systems, we can only here say that the investigation of the constitution of molecules by means of their vibrations, as indicated by spectroscopic observations, will be greatly assisted by a thorough study of this part of the volume.

We have not space to say anything of what to many readers must be one of the most interesting parts of the book—that on continuous calculating machines, in which pure rolling friction is taken from the class of unavoidable evils, and raised to the rank of one of the most powerful aids to science. Rolling and sliding have been more than once combined in the hope of obtaining accurate measurements, but the combination is fatal to accuracy, and these new machines, one at least of which has been actually constructed and used, are the first in which pure rolling friction has had fair play given it as a method of mechanically accurate integration.

A method is also given of combining a number of disk, globe, and cylinder integrators, so as to form a machine the motions of two pieces of which are related to each other by a differential equation of any given form. These machines all work in a purely statical manner, that is, in such a way that the kinetic energy of the system is not an essential element in the practical theory of the machine (as in the case of pendulums, &c.), but has to be taken into account only in order to estimate the magnitude of the tangential forces at the points of contact which might, if great enough, produce slipping between the surfaces. Thus, by means of a machine, which will go as slowly as may be necessary to keep pace with our powers of thought, motions may be calculated, the phases of which in nature pass before us too rapidly to be followed by us.

In the original preface some indications were given of what we were to expect in the remaining three volumes of the work. We hope that the reason why this part of the preface is omitted in the new edition is that the work will now go on so steadily that it will be unnecessary to preface performance by promise.

J. CLERK MAXWELL

ARTIFICIAL MANURES

On Artificial Manures, their Chemical Selection, and Scientific Application to Agriculture. A Series of Lectures given at the Experimental Farm at Vincennes, during 1867 and 1874-5. By M. Georges Ville. Translated and Edited by W. Crookes, F.R.S. (London: Longmans and Co., 1879.)

THOSE who take up this volume with the hope of finding the chemistry of artificial manures fully treated will be much disappointed. Not only are many of the commonest manures scarcely mentioned, but some of the most important and practical aspects of the subject are never noticed. The behaviour of manures after they come in contact with the soil is surely of the greatest importance. Chemical investigations have long ago proved that some of the ingredients of manure—as phosphoric acid and potash—are firmly held in combination by the soil, while others—as nitric acid, chlorine, and soda—are feebly retained, and readily pass away in the drainage water after rain. It has also been abundantly proved that though ammonia is firmly retained by a fertile soil, it rapidly undergoes conversion into nitric acid, which is easily washed out. The practical conclusion from these facts is plain. Diffusible manures must be applied only when the crop can make immediate use of them. Now, though M. Ville speaks voluminously concerning the application of phosphates, nitrates, and ammonium salts, no reference to the facts just indicated is to be found in his book, beyond the mere statement that clay is capable of temporarily retaining potash and ammonia.

The lectures of M. Ville are chiefly occupied by the consideration of the present state of agriculture in France, and by the recommendation of a system of artificial manuring of which he regards himself as the inventor. The condition of French agriculture is clearly, as a whole, very low; the existence of the peasant and small farmer is only maintained by the exercise of much thriftiness and self-denial. To improve this condition M. Ville very

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properly recommends the consolidation of the land in large farms, and the liberal use of artificial manures.

The "normal manure" which M. Ville recommends is in its simplest form a mixture of superphosphate, saltpetre, and gypsum, thus supplying nitrogen, phosphoric acid, potash, and lime. Instead of employing the nitrate of potassium, a mixture of nitrate of sodium or sulphate of ammonium with chloride of potassium may be substituted; the manure then becomes a "normal homologous manure." This normal manure embraces all the chief elements of plant food which it may be necessary to apply to the land. It is unnecessary, however, to apply the entire mixture to every crop. Each crop demands a preponderance of one or other of the constituents of the manure; this "dominant" constituent is therefore increased when the manure is prepared for a particular crop; or the elements of the whole manure may be distributed through a rotation of crops, each crop receiving the part specially suited to it. Stated thus, we can only approve the recommendations which M. Ville has made; they are in fact, in their last-named form, precisely carried out by all our best farmers in the present day. Though, however, we have correctly stated the teaching which may be gathered from his book, there are many passages in the lectures which urge the return to the land of all the potash, phosphates, and lime which the crops have removed, a proceeding which is on many soils quite unnecessary, and therefore, very unremunerative.

M. Ville recommends that each farmer should set aside a small portion of his land to be treated with experimental manures. One plot of this ground would receive the normal manure; a second the same without nitrogen; a third the same without phosphates; a fourth the same without potash; while another plot would be left entirely without manure. By growing crops on these plots the farmer would learn in the most certain manner what elements of plant food were chiefly deficient in his soil in relation to the crops he wished to grow. This is excellent advice; no better could be given. It is only by such experiments that the true condition of the soil can be revealed; and it is only by thus testing the effect of manures before applying them on a large scale that an economic return can reasonably be expected. France is apparently ahead of us in the practical use of such experiments. Thanks to the centralisation which places the control of everything in the hands of the Government, field experiments of this description are now in progress in thirty-four farming schools throughout the country, while simpler experiments on the effects of manures have been established in connection with 350 day schools. In England we have but one place at which such experiments are thoroughly carried out, namely, Rothamsted.

Are we, then, to credit M. Ville with the discovery of the great effect to be obtained from artificial manures, or of the best mode of applying them? He claims for himself the honour of having discovered the principles he sets forth, and compares himself with Lavoisier, and his detractors with the detractors of that great man, and concludes:—"We must allow time to complete the work of justice, and give to every one his proper place." We will in reply simply mention a few dates. The famous field experiments at Rothamsted commenced in 1843; in the very first year trials were made of the effects of phosphates, potassium, magnesium, and ammonium salts. These field experiments have been carried on continuously up to the present time, and the effect of every variety of combination of manure has been shown in the fields devoted to wheat, barley, beans, clover, roots, pasture, and potatoes. That nitrogen should form the "dominant" constituent of a manure for wheat, and phosphates the dominant constituent of a manure for turnips, was clearly proved in the first two or three years of the experiments; and by 1849 the character of potash as the proper dominant in the case of beans and clover was also established. With these experiments M. Ville is well acquainted. Our last date shall be taken from his own book. The first field experiments made by M. Ville at Vincennes commenced in 1860.

The book contains several extraordinary statements. It would take too long to discuss M. Ville's views as to the assimilation of the free nitrogen of the air by all crops, but especially by the leguminosæ; immense quantities of nitrogen are, according to him, thus acquired. We are curious to know what authority he has for stating that when an animal is fed on hay one-third of the nitrogen is lost "in the act of digestion," and that another third is lost during the fermentation of the animal manure, so that only one-third of the original nitrogen is at last returned as manure to the land.

We cannot conclude without calling attention to the extremely untrustworthy character of the figures throughout the book. On p. 54 the mould on an acre of soil weighs 400,000 tons; on p. 180 it weighs 1,600 tons. On p. 353 the weight of resin yielded by an acre of pine trees is given as 4–5 cwts., but immediately after it is stated to be 1,122–1,540 lbs. The quantities of nitrogen to be applied are a complete puzzle. To take a single instance: On p. 238 we are told that to obtain a good crop of beet we must apply 70 lbs. of nitrogen per acre. On p. 357 the quantity has risen to 176 lbs. On pp. 367 and 368 the formulæ for the beet manures are given; each formula is stated to contain 187 lbs. of nitrogen; but on looking at the ingredients only 83 and 85 lbs. of nitrogen are found to be contained by the ammonium salts and nitrates employed. Finally, on p. 374 we are told that the nitrogen applied to beet should amount to 70–88 lbs. per acre. What are we to believe?

Both the old and new chemical notations are employed in the course of the book. R. W.

OUR BOOK SHELF

Lecture on the Gault. By F. G. H. Price. (Taylor and Francis, 1879.)

THIS pamphlet contains considerably more than a lecture, embodying a list of the French and English works upon the Gault, which have come under the author's notice, and nearly forty pages of tables of fossils.

The description of the gault at Folkestone has been amplified from that read by the author before the Geological Society.[1] He maintains his subdivision of the gault at Folkestone into beds, and endeavours to correlate with them, to some extent, the gault to the west. The outcrop at Eastbourne is separately described, and found to contain an unexpectedly long list of fossils. The Blackdown beds are included in the Gault, which is to be greatly regretted, for there is every reason to suppose that

[1] *Quart. Journ. Geol. Soc.*, 1874, vol. xxx. p. 342.

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